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Temporal Variations in Fibril Orientation

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Abstract. We measure variations in orientation of fourteen dynamic fibrils as a function of time in a small isolated plage and nearby network using a 10-min time sequence of Hα filtergrams obtained by the Dutch Open Telescope. We found motions with average angular velocities of the order of 1 deg min^{-1} suggesting systematic turning from one limit position to another, particularly apparent in the case of fibrils with lifetimes of a few minutes. Shorter fibrils tend to turn faster than longer ones, which we interpret as due to vortex flows in the underlying granulation that twist magnetic fields.

1. Introduction

The solar chromosphere is filled with fibrils in plages and mottles in network seen on the disk and with spicules seen at the limb. Although the mutual correspondence of fibrils, mottles, and spicules has not yet been established directly, we believe that they represent the same feature seen under different circumstances (cf. Christopoulou et al. 2001). Their ubiquity is especially evident in images taken at the center of strong spectral lines. So far most effort has been directed towards understanding their nature, internal structure (De Pontieu et al. 2004; Tziotziou et al. 2003, 2004), and drivers (Hansteen et al. 2006; De Pontieu et al. 2007). Less attention has been paid to their less obvious tangential motions (i.e., perpendicular to the axis) which may betray braiding of chromospheric magnetic fields due to vortex granular flows underneath (Brandt et al. 1988). The first spectroscopic observation of spicule motions parallel to the limb was made by Pasachoff et al. (1968). Nikolsky & Platova (1971) reported on the quasi-periodic motion of spicules along the limb with tangential velocities of 10–15 km s^{-1} and amplitudes about 1 arcsec. Mamedov & Orudzhev (1983a,b) pointed out the similarity between radial (i.e., along the line-of-sight) and tangential velocities of spicules along the limb and speculated on the motion of spicules as a whole.

In this paper, we study tangential motions of fibrils in a small isolated plage and nearby network using a 10-min time sequence of Hα filtergrams obtained with the Dutch Open Telescope (DOT). We concentrate on relatively short-lived straight dynamic fibrils (henceforth DFs, de Wijn & de Pontieu 2006) exhibiting conspicuous elongation and/or retraction within a few minutes. Longer, more static or more curved fibrils are not considered here. We for the first time present measurements of temporal variations in DF orientations. They suggest a relation between angular velocity and DF length.

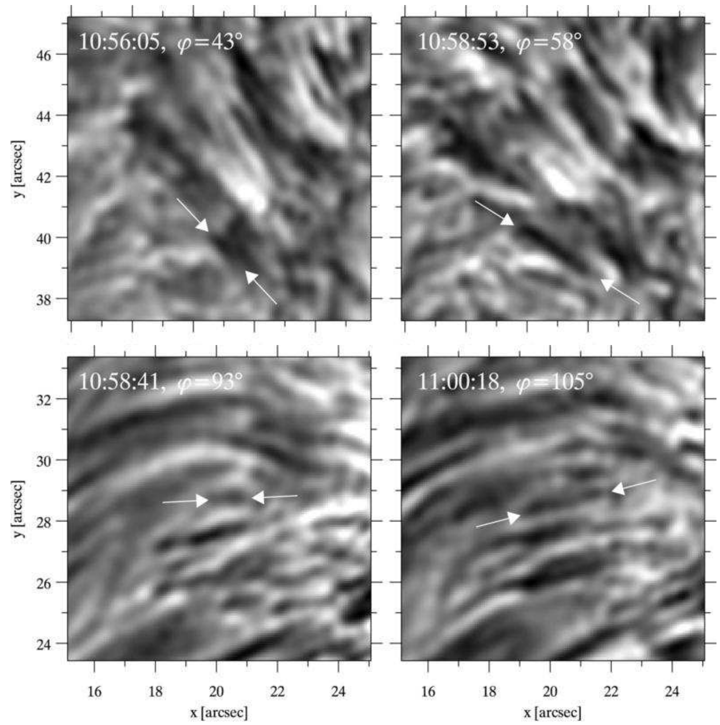

Figure 1. The orientations and lengths of two fibrils highlighted by arrows at intervals of 2.8 min (upper panels) and 1.6 min (lower panels). The angle φ is measured clockwise from the fibril to the righthand y-axis.

2. Observations and Measurements

We use data from the DOT obtained on April 24, 2006 for an isolated plage at $\mu = 0.768$. A tomographic multiwavelength image sequence was recorded during excellent seeing from 10:53:05 UT until 11:02:54 UT. The seeing quality measured at the G band by the average, maximum, and minimum Fried parameter r_0 was 13.0, 16.2, 8.6, respectively. The processed data and movies are available at `http://dotdb.phys.uu.nl/DOT/`. The burst cadence was 12 s. The resulting time sequence was reconstructed by speckle masking and other steps as summarized in Rutten et al. (2004). In this study, we analyse the 10-min sequence of Hα filtergrams taken by the DOT Lyot filter (Gaizauskas 1976) with a FWHM passband of 0.025 nm at $\Delta\lambda = -0.03$ nm from line center.

Inspecting the Hα movie frame-by-frame we focused on relatively short-lived ($\approx$5 min), straight DFs exhibiting apparent elongation or/and retraction. We identified fourteen such DFs and measured the image coordinates of the apparent feet and tops per individual frame. Because the feet locations also vary with time we used the time-averaged feet positions as references. We measured the DF orientations with respect to the y-axis (terrestrial north) and the DF lengths along lines connecting their tops and reference foot locations. Figure 1 shows two examples.

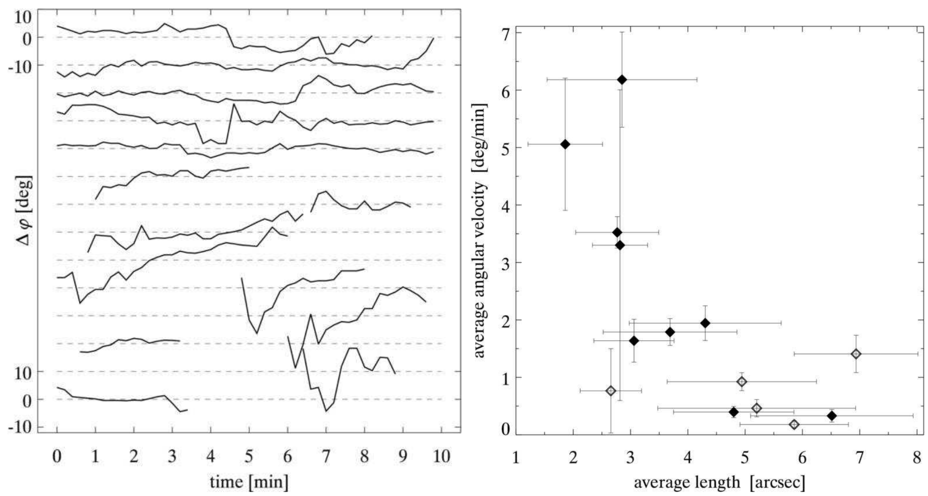

Figure 2. *Left:* Temporal variations in fibril orientation $\Delta\varphi$ measured as difference with the average value represented by dashed lines. The shifts of the curves in time correspond to the fibril occurrence within the image sequence. *Right:* Average angular velocities of the orientation variation versus average fibril length. The filled and empty diamonds represent fibrils turning counterclockwise and clockwise, respectively.

3. Results

Figure 2 shows the measured variations in orientation for the fourteen selected DFs and the rate of change in orientation inferred from linear fits to the curves at left plotted against average DF length. Although the measurements suffer from uncertainty and subjectivity, systematic trends appear. The orientation variations of some short-lived DFs can be characterised as a progression between sign changes, i.e., orientation change from one limit position to another. In contrast, the DFs present during the whole time sequence show stable orientation with only episodic deviations from the average value. Figure 2 suggests that the angular turning speed may be related to DF length, and that shorter DFs turn faster than longer ones. The average fibril lengths and angular velocities yield an estimate of centrifugal acceleration of $1\,\mathrm{m\,s^{-2}}$.

4. Discussion

Because of projection and the magnetic nature of DFs (De Pontieu et al. 2004, 2007; Hansteen et al. 2006), we interpret the temporal variation of the measured fibril orientation as a sum of variations in azimuth and inclination of magnetic flux tubes with respect to the local vertical. In the context of force-free fields (e.g. Lüst & Schlüter 1954), the phenomenon may indicate field twisting and braiding by vortex granular flows beneath (Brandt et al. 1988), injection of twist into the corona, and twisted coronal fans seen in TRACE EUV movies. On the basis of the indicated relation between angular velocity and length (Fig. 2) we suggest that granulation with larger vortical flows produce more upright flux tubes, i.e., faster turning and shorter in projection on the disk, but better seen as long spicules at the limb with conspicuous tangential motions as reported in Pasachoff et al. (1968), Nikolsky & Platova (1971), and Mamedov & Orudzhev (1983a,b). In contrast, granulation with smaller or no vortical flows permits more slanted flux tubes with smaller angular velocities, longer in on-disk projection but hardly observable on the limb because of crowding. Measurements of the horizontal flow fields in the photosphere and elimination of the projection effects are needed to test this scenario. The observed angular velocity of $\approx 1\,\mathrm{deg\,min^{-1}}$ implies more intensive twisting of the field lines than in sunspots which have typical rotation velocities of about $1\,\mathrm{deg\,h^{-1}}$ (Kucera 1982; Brown et al. 2003).

5. Summary

Using a time sequence of high-resolution Hα filtergrams obtained by the DOT we have searched for temporal variation in the azimuthal orientation of fourteen dynamic fibrils. They show significant variation, for shorter-lived fibrils indicating turning motions at about $1\,\mathrm{deg\,min^{-1}}$. Shorter DFs turn faster than longer ones, which may indicate difference in granulation vorticity. This conjecture suggests measurements of horizontal flow fields in the photosphere together with elimination of the projection effects in fibril imaging.

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